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MONTHLY NOTICES
OF THE
ROYAL ASTRONOMICAL SOCIETY.

VOL. LIX. No. 9. JUNE 1899.

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VOL. LIX.

JUNE 9, 1899.

No. 9

Professor G. H. DARWIN, M.A., LL.D., F.R.S., President, in
the Chair.

Frederick Evan Peach, 161 Stanstead Road, Forest Hill, S.E.
was balloted for and duly elected a Fellow of the Society.

The following candidates were proposed for election as Fellows
of the Society, the names of the proposers from personal
knowledge being appended :—

W. C. Plummer, The Owens College, Manchester (proposed
by William Esson); and
Clement Jennings Taylor, Port Elizabeth, Cape Colony
(proposed by L. A. Eddie).

Seventy-six presents were announced as having been received
since the last meeting, including, amongst others :—

Berlin Observatory, Resultate aus Beobachtungen 1892-97,
and Potsdam Observatory, Photographische Himmelskarte,
Band 1, presented by the Observatories; R. Brown, Researches
into the origin of the Primitive Constellations of the Greeks,
Phœnicians, and Babylonians, presented by Mr. Lynn; Wilhelm
Olbers's Leben und Werke: Neue Reduktion der in 1795 bis
1831 angestellten Beobachtungen von Kometen und kleinen
Planeten, presented by Professor Schur.

A further Investigation concerning the Position Error affecting Eye-estimates of Star Magnitudes. By Alexr. W. Roberts.

In No. 6, vol. lvii. of the *Monthly Notices*, I entered upon an investigation dealing with the amount and nature of the position error affecting visual determinations of star magnitudes. The results obtained in that article were based on an examination of the differences between the direct and reverse magnitude determinations of a group of stars surrounding the short period variable Lac. 5861. Since then it has seemed to me an important addition to the investigation to consider only naked-eye estimates of star magnitudes.

Results based on such estimates would be entirely free from the suspicion that the error might possibly be due to instrumental causes. Further, a comparison could be instituted between the results obtained from naked-eye observations (observations made with both eyes) and the results obtained from telescopic observations (one eye only being used); and this comparison would indicate if the amount and character of the variation were the same whether the right or left eye was used in making the observations.

Several groups of stars were available for the proposed investigation; the same conclusion, however, can be arrived at, and more directly, by considering only two stars, instead of several stars, of a group.

North and south of the well known short period variable κ Pavonis are two stars of almost equal magnitude, which have been regularly used along with others in the near neighbourhood as comparison stars for κ Pavonis.

The two stars and their positions are

	^h	^m	^s		
ζ Pavonis	18	28	25	-71° 31' 50" (1875)	
λ Pavonis	18	40	38	-62 19 38	

It was the constantly changing magnitudes of these two stars, as observations in varying hour angles were made, that first impressed me with the reality of the phenomenon of position error, and the importance of a thorough investigation as to its nature.

As the hour angle of the stars varies, it is evident that their relative position will also vary. Sub-polo, λ Pavonis is the lower of the two stars, and it then seems at least half a magnitude brighter than ζ Pavonis.

As the stars rise higher and higher this difference in brightness diminishes, until at an altitude of 50° the two stars seem equal in magnitude. As the stars rise to their upper culmination ζ Pavonis becomes the brighter, reaching its maximum brightness relative to λ soon after passing the meridian. It then decreases in brightness as its distance below λ Pavonis diminishes,

becoming soon after passing its lower culmination, as already said, half a magnitude fainter than λ Pavonis.

This states generally the relation of the variation in the brightness of the two stars to their varying relative positions. We are able, however, as in the case of the stars surrounding Lac. 5861, to deal more rigorously with the matter.

It is evident that as ζ Pavonis and λ Pavonis circle round the heavens they take up relatively the same position to one another as they would if they revolved round a point midway between the stars. Practically, therefore, for the question to be considered, we may regard ζ and λ Pavonis as revolving round this point instead of moving round the heavens.

The co-ordinates of this middle point, which we may call O, are

$$\text{R.A. } 18^{\text{h}} 35^{\text{m}} 40^{\text{s}} (1875)$$

$$\text{Dec. } -66^{\circ} 56' 9''$$

and the angle formed between the line joining the two stars and the line passing through O and the pole is

$$7^{\circ} 7' 26''.$$

Let m_i be the true magnitude of ζ Pavonis, then this magnitude will be affected by

- (1) *Atmospheric absorption.* The amount of loss due to this cause can be expressed by the quantity $k \sec z$, k being the co-efficient of absorption and z the zenith distance of the star.
- (2) *Relative position with regard to O.* It would appear that the simple trigonometrical expression

$$p \cos (\theta - M),$$

where θ is the parallactic angle of O, satisfies the variation in magnitude due to this cause. A second term

$$q \cos (2\theta - N)$$

was added in the first discussion of the observations, but it was found that the number of unknown quantities then introduced would overburden the equations.

Thus at any instant of time the observed magnitude of ζ Pavonis will be

$$m_i + k \sec z_i + p \cos (\theta - M).$$

Similarly the observed magnitude of λ Pavonis, at the same instant, will be

$$m_\lambda + k \sec z_\lambda - p \cos (\theta - M);$$

and the difference between the observed magnitudes of the two stars,

$$(m_i - m_\lambda) + k (\sec z_i - \sec z_\lambda) + 2p \cos (\theta + M).$$

As the difference between the magnitudes may vary continually during the period over which the observations extend, to the above expression a term

$$m' (t-1895)$$

should be added.

Putting,

$$m_{\zeta} - m_{\lambda} = x$$

$$\sec z_{\zeta} - \sec z_{\lambda} = s$$

$$2p \cos M = a$$

$$2p \sin M = \beta$$

the type of equation of condition connecting the observed magnitudes of ζ and λ *Pavonis* becomes

$$\text{obs. mag. of } \zeta - \text{obs. mag. of } \lambda = x + m' (t-1895) + sk + a \cos \theta + \beta \sin \theta.$$

In the following table are given all the data necessary for the determination of the unknown quantities

$$x, m', k, a, \text{ and } \beta$$

It may be stated that the differences between the observed magnitudes of ζ and λ are not obtained by direct comparison when the amount of difference is as great as $0^m.5$, or even less.

In this case intermediate magnitudes are used as sequences.

Rot. No.	No of Obsns.	(t-1895)	Sec z_{ζ} -Sec z_{λ}	Hour Angle of ζ .	Par. Angle of $\zeta=\theta$.	$\zeta-\lambda$.	Weight.	Computed $\zeta-\lambda$.
				h m	°	m		m
1	2	+0.3	-3.73	13 54	24.2	+0.40	1	+0.37
2	5	0.9	2.05	14 58	37.7	+0.50	2	+0.51
3	17	0.4	1.13	15 55	49.4	+0.48	3	+0.53
4	25	0.6	0.53	16 53	61.6	+0.48	4	+0.51
5	24	0.7	0.22	17 55	74.8	+0.49	4	+0.43
6	30	0.4	-0.04	18 57	88.5	+0.40	4	+0.29
7	23	0.3	+0.04	19 56	102.5	+0.23	4	+0.13
8	12	0.1	0.08	20 58	118.9	-0.23	3	-0.08
9	11	0.3	0.11	21 56	136.1	-0.48	3	-0.30
10	15	1.5	0.13	22 50	154.3	-0.65	3	-0.48
11	13	1.3	0.14	23 56	178.5	-0.66	3	-0.70
12	10	0.9	0.15	0 55	200.4	-0.71	3	-0.85
13	8	0.6	0.15	1 53	220.4	-0.75	3	-0.86
14	5	1.0	0.13	2 52	238.4	-0.82	2	-0.85
15	4	1.1	0.10	4 0	256.5	-0.72	2	-0.70
16	6	+0.9	+0.06	4 47	267.8	-0.65	2	-0.55
17	3	-0.	-0.06	5 58	283.7	-0.50	1	-0.40

The resulting normal equations are—

$$\begin{aligned}
 &+47.00x + 31.30m' - 11.42k + 9.09a - 15.74\beta = -6.08 \\
 &+31.30x + 28.24m' - 5.53k + 10.12a - 5.08\beta = -8.57 \\
 &-11.42x - 5.53m' + 27.83k + 12.23a + 9.59\beta = -8.43 \\
 &+9.09x + 10.12m' + 12.23k + 17.51a + 4.36\beta = -13.30 \\
 &-15.74x - 5.08m' + 9.59k + 4.36a + 29.48\beta = -12.18
 \end{aligned}$$

which being solved gives

$$\begin{aligned}
 x &= -0.14 \\
 m' &= +0.02 \\
 k &= +0.07 \\
 a &= -0.65 \\
 \beta &= -0.41
 \end{aligned}$$

and

$$\begin{aligned}
 M &= 21^{\circ} 30' \text{ or } 32^{\circ} 30' \\
 2p &= +0^m.77.
 \end{aligned}$$

Therefore,

Mag. of ζ Pavonis — Mag. of λ Pavonis

$$= 0^m.14 + 0^m.02 (\theta - 1895) + 0^m.07 (\sec z_i - \sec z_\lambda) + 0^m.77 \cos (\theta - 32^{\circ} 30').$$

The values computed from this final equation are given in the last column of the preceding table. It may be objected that the residuals are large: this may be admitted, but that they are so arises, no doubt, from the impossibility of expressing the varying sensitiveness of different portions of the retina in an exact mathematical form.

We may consider now the several results obtained.

(1) *Magnitude of ζ and λ Pavonis.* The magnitude of ζ Pavonis, as obtained from observations, is $4^m.30$: the value of λ Pavonis consequently is $4^m.30 - x = 4.44$. The U.A. values are 4.20 and 4.30 respectively. The small value of m' , $0^m.02$, a quantity less than its weight, indicates still further the permanence of the light of both stars.

(2) *Co-efficient of atmospheric absorption.* The value obtained in the present investigation for this important coefficient is

$$+ 0^m.07.$$

It is possible that this value is slightly too small. I am convinced, however, that the value obtained at Harvard from observations made in the years 1886, 1887, and 1888, and the value generally accepted, is too great, at least for these latitudes of dry atmosphere and clear skies.

The Harvard value is

$$+0^m.39.*$$

This would mean that a first magnitude star could not be seen on the horizon. Every clear night at this season I can roughly time my watch by the setting of *Sirius*. As the star reaches the horizon, a straight black line against the dark blue beyond, it flickers for a few seconds, then disappears. Sixth magnitude stars have also been discerned at an altitude of 5° .

From considerations such as these, as well as from the definite value obtained in this paper, it is certain that the value of the coefficient of absorption cannot be greater than one-tenth of a magnitude for places with the same atmospheric conditions as Lovedale.

(3) *Amount and character of Position Error.* The expression

$$0^m.77 \cos (\theta - 32^\circ 30')$$

indicates that the maximum variation due to relative position is reached when the parallactic angle of the centre O is $32^\circ 30'$. Now the line joining ζ and λ makes an angle of $7^\circ 7'$ with the meridian line: thus the apparent difference between the brightness of ζ and λ *Pavonis* is greatest when the line joining the two stars makes an angle of $25^\circ 23'$ with the vertical.

A simple diagram may explain this far more directly and clearly than a literal or trigonometrical statement.

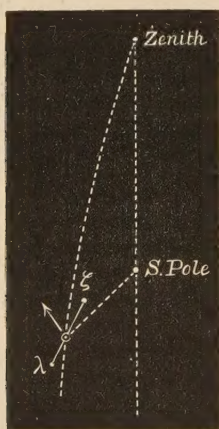


FIG. 1.

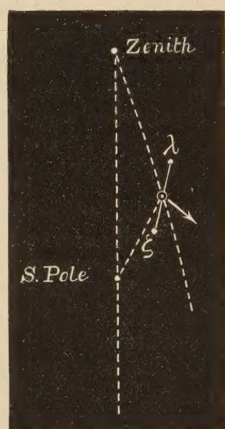


FIG. 2.

In Fig. 1 we have the position of λ with respect to ζ when the magnitude of λ with relation to ζ seems at a maximum. In Fig. 2 the magnitude of λ is at a minimum with relation to ζ *Pavonis*.

* *Harvard Annals*, vol. xix, Part 2, p. 252.

In the investigation already referred to at the beginning of this paper (*Monthly Notices*, vol. lvii. April 1897, p. 483) I obtained an angle of 32° with the vertical, as that at which the lower of two stars seemed to reach its maximum brightness.

In this investigation the angle arrived at is $25^\circ 23'$. The difference of $6\frac{1}{2}^\circ$ is accounted for by the fact that however great the care taken to keep the position of the head erect, there is always a small inclination when looking through an ordinary theodolite, the instrument used at Lovedale. On the other hand, in naked-eye determinations there is no tendency to any inclination of the head.

Combining both results the following definite conclusions regarding the influence of relative position on apparent magnitude may be accepted :

- (1) Through the unequal sensitiveness of the retina the lower of two stars will appear relatively brighter than it actually is.
- (2) The maximum increase in relative brightness does not take place when one star is directly under the other, but *after* it has passed the vertical. The angle of maximum variation is about 30° .
- (3) The amplitude of relative change due to this cause amounts to no less than three-fourths of a magnitude.
- (4) The similarity between the results obtained when both eyes are used, and when only one is used, naturally points to the fact that the error is of the same magnitude and character whichever eye is used.

A simple experiment settled the locus of the error. I had rather inclined to the view that the *seeming* variation was more mental than physiological—that, in fact, the eye saw perfectly enough, but the brain behind, for some reason or another, put its own interpretation on the sensations presented to it.

When the constellation *Pavo* was low down, and when therefore λ seemed about $0^m.8$ brighter than ζ , I adopted an exceedingly undignified mode of observation—viz. looking at the constellation with head downwards, my two legs being the window through which the observations were made.

To my thus looking the positions of the stars were the same as they would be if viewed in orthodox fashion: *Pavo* did not seem upside down. The brain had received the picture presented to it, but from association or some other mental sense it turned the impression upside down, thus making the view appear more real.

There was this important difference however, λ *Pavonis* was no longer $0^m.8$ brighter than ζ ; it was instead over half a magnitude fainter.

Indeed, all the magnitudes of the stars in the neighbourhood were what they would be after an interval of twelve hours. No more decisive proof could be forthcoming of the cause of

the variation. It was entirely confined to the retina. Further, the phenomenon is in no way restricted to one or two observers. If this were so I would not enter so fully into the matter. Instead of being restricted, I believe it to be a condition of vision.

I have already referred to well-known observers, Barnard, Pickering, and Chandler, who have abundantly testified to its existence, as far as they were concerned. Recently Dr. W. J. S. Lockyer, in his valuable dissertation on the period of η *Aquila*, finds that Schmidt's observations are affected by a systematic error depending on the relative position of the variable and its comparison stars.

Indeed, there are few observers who have made the visual determination of star magnitudes a particular line of research who have not been brought face to face with the difficulty.

Lovedale: 1899 May.

Note on the Construction and Use of Réseaux.

By Arthur R. Hinks, M.A.

Very little has been published on the construction and use of *réseaux* since Professor Vogel described in the *Bulletin du Comité Permanent*, vol. i. p. 86, the experiments undertaken by Dr. Scheiner, when, at the inauguration of the Astrographic Chart, the study of the subject was confided to the Potsdam Observatory. A few scattered references show that astronomers engaged on the chart work have generally followed Dr. Scheiner in endeavouring to secure extreme fineness of the photographed image of the *réseau* by the use of very finely ruled *réseaux* placed very nearly in contact with the plate.

Some experiments which I made last year suggest that this procedure may with advantage be modified.

In the first place, it seems doubtful if one should aim at making the image of the *réseau* line as fine as a micrometer wire, unless Professor Turner's form of micrometer is used, in which the point of intersection of the line with a glass scale has to be *estimated*. It is certainly easier to set a wire upon a line well defined, but broader than itself.

Secondly, it is inconvenient to be obliged to place the plate very close behind the *réseau*. The use of commercial plates at any time is then quite out of the question, since they frequently deviate from flatness by several tenths of a millimetre. And even patent plate-glass plates occasionally have sufficient curvature to bring them into contact with and cause damage to the *réseau*.

The lines in the Gautier *résseau*, No. 86, belonging to the Cambridge Observatory, are about $0^{\text{mm}}\cdot01$ wide. A plate was placed behind this in a tilted position, so that one end was in contact with the *résseau* and the other end separated from it by a measured amount. The definition of the image fell off very rapidly, and with a separation greater than $0^{\text{mm}}\cdot05$ the lines were fuzzy and the first pair of diffraction bands conspicuous.

Now the distance between the first pair of minima in the diffraction pattern varies directly as the distance between the *résseau* and the plate and inversely as the width of the *résseau* line, and this suggested that a wider line might give a sharper image. I silvered some glass plates and ruled a number of lines of various widths. Exposures on plates tilted behind these experimental *réseaux* showed that the lines about $0^{\text{mm}}\cdot02$ wide gave on the whole the best results. The definition of the image was scarcely impaired with a separation of $0^{\text{mm}}\cdot5$, and fell off slowly beyond that.

M. Gautier has, in accordance with this result, made for the Observatory another *résseau*, No. 88, in which the lines were to be $0^{\text{mm}}\cdot02$ wide. They are actually very slightly narrower than this. But the new *résseau* is a very great improvement on the old one, and we have been able, without damage to the silver film, to impress good images of it on the commercial plates at present used with our five-inch portrait lens. I believe, then, that it will be found that an increase of the width of the ruling to $0^{\text{mm}}\cdot02$ is of great advantage. It should bring nearer the time when every celestial photograph has a *résseau* impressed on it.

Various methods have been employed for impressing the *résseau* upon the plate, but they nearly all agree in the use of parallel light. The most general practice seems to be to put the *résseau* slide over the object-glass and use a small source of light in the focal plane of the telescope. This is troublesome, and it seems to me to be unnecessary, if not actually disadvantageous. I believe that it would be better to use a small source of light placed at a distance from the *résseau* equal to the focal length of the telescope, without any collimator.

We cannot use a source of light which is practically a point source, because the exposure required is inconveniently long. If we use light coming through a diaphragm of, say, $\frac{1}{4}$ -inch aperture, the geometrical divergence of a pencil of light passing through the *résseau* is the same in both cases, and in any case the consequent widening in the image is negligible in comparison with the effects of diffraction.

If we use divergent light, the scale value of the image is altered by a small amount depending upon the separation between *résseau* and plate and the distance of the light source. But this is of no importance whatever. The angular value of the *résseau* interval is quite arbitrary, depending in the first place upon the mean focal length of the objective, which may easily differ from

its designed value by several times the separation between *réseau* and plate ; and in the second place upon the actual focal length as affected by temperature from day to day.

It appears, then, that we lose nothing by employing light diverging from a source at the focal distance instead of the more or less parallel light from the same source in the focus of a collimator. And in one respect we gain. Suppose the plate is not flat. There will be irregular distortion in the field, since the stars are projected from the centre of the objective. If we put on the *réseau* with parallel light, there is no distortion of its image on the plate ; if with light from a source at a distance from the plate equal to the focal length, the distortions of the *réseau* image are approximately the same as the distortions of the neighbouring stars, unless the irregularities in the plate are very abrupt. We have thus a method of avoiding to a large extent the accidental errors due to curvature of the plate.

My conclusions are, then, that it is advisable to increase the width of the ruled *réseau* lines to 0^{mm}·02, and to impress them on the plate by light from a source placed without any collimator at a distance equal to the focal length of the photographic objective.

Cambridge Observatory :
1899 June 6.

On the formulæ of reduction to the meridian of the observed zenith distances of stars. By A. E. Young.

The author being unable to reconcile the formulæ given in the "Handbook of Professional Instructions for the Trigonometrical Branch, Survey of India Department," p. 177, for the correction to the observed zenith distance of a star for instrumental error, with those given by Chauvenet in his "Spherical and Practical Astronomy," 5th ed. vol. ii. pp. 290-291, for the meridian circle, was led to an examination of the latter, from which it appears that the discrepancies were caused in the first place by some small terms having been neglected by Chauvenet in forming the expansion for the correction, and in the second to his having assumed that the correction to what he calls the instrumental declination is the same as the correction to the instrumental zenith distance of the star. At any rate, the latter assumption is made in the example he gives. These assumptions, which involve neglecting terms depending on n only, will hardly affect observations made with the meridian circle, in which n is usually very small ; but in the case of a portable altazimuth or zenith telescope they may have an appreciable effect, and it will be inter-

esting to examine them and, at the same time, show how to deduce the survey of India formulæ from Chauvenet's.

The instrumental declination δ' is really the difference between the readings on the pole and on the star subtracted from 90° . In practice, however, the reading on the pole cannot be obtained, so that a correction must be computed for it and combined with the correction to the reading on the star. For let

z_p = observed reading on pole
 z_s = " " " " star

and let $\Delta p, \Delta s$ be the corrections to these for instrumental error, so that

$$\begin{aligned} z_p + \Delta p &= \text{true Z.D. of pole} \\ z_s + \Delta s &= \text{,, ,, star.} \end{aligned}$$

Then, in the case of a star north of the zenith,

$$\begin{aligned}\delta' &= 90^\circ - (z_p - z_s) \\ \delta &= 90^\circ - \{(z_p + \Delta p) - (z_s + \Delta s)\} \\ \therefore \delta' - \delta &= \Delta p - \Delta s \\ \therefore \Delta s &= \Delta p - (\delta' - \delta)\end{aligned}$$

and, in the case of a star south of the zenith,

$$\Delta's = (\delta' - \delta) - \Delta p = -\Delta s.$$

Taking the last of Chauvenet's three equations (191), we have

$$[\cos \delta \cos (\tau - m) = \cos c \cos \delta',$$

Put $\delta' = \delta + h$ and expand, then

$$\cos \delta \cos (\tau - m) = \cos c (\cos \delta - h \sin \delta)$$

or

$$h = \cot \delta \left\{ 1 - \cos \frac{(\tau - m)}{\cos c} \right\}.$$

Expanding $\cos (\tau-m)$ and $\cos c$ to two terms,

$$h = \delta' - \delta = \frac{\cot \delta}{2} \{(\tau - m)^2 - c^2\} \quad , \quad , \quad , \quad , \quad (A)$$

If we insert for c its value $(\tau - m) \cos \delta - n \sin \delta$, this reduces to

$$\begin{aligned}\delta' - \delta &= \frac{\cot \delta}{2} \{ (\tau - m)^2 - (\tau - m^2) \cos^2 \delta + 2n(\tau - m) \sin \delta \cos \delta - n^2 \sin^2 \delta \} \\ &= \frac{(\tau - m)^2}{4} \sin 2\delta + n(\tau - m) \cos^2 \delta - \frac{n^2}{4} \sin 2\delta.\end{aligned}$$

This is the complete expression for the correction to an observed zenith distance for instrumental error, and by substituting in it the values of a , b , and c , the numerical value will be found.

Correction for Collimation Error c.—Suppose $a=0$ and $b=0$ then

$$n=0 \text{ and } \tau-m=c \sec \delta$$

$$\therefore \Delta s = -\frac{\cot \delta}{2} c^2 \frac{(1 - \cos^2 \delta)}{\cos^2 \delta} = -\frac{c^2}{2} \tan \delta$$

for a north star, and $+\frac{1}{2}c^2 \tan \delta$ for a south star. Of course, if the star is south of equator δ will be negative, and the sign of the correction will be reversed.

Correction for Azimuthal Deviation.—Put $b=0$ and $c=0$, then

$$n = -a \cos \phi, \tau-m = -a \cos \phi \tan \delta$$

$$\Delta s = \frac{\tan \phi}{2} \cdot a^2 \cos^2 \phi - \frac{\cot \delta}{2} (a^2 \cos^2 \phi \tan^2 \delta)$$

$$= \frac{a^2}{2} (\sin \phi \cos \phi - \cos^2 \phi \tan \delta)$$

$$= \frac{a^2 \cos \phi \sin (\phi - \delta)}{2 \cos \delta}$$

$$= -\frac{a^2 \cos \phi \sin z}{2 \cos \delta}$$

for both north and south stars.

Correction for Dislevelment of the Transit Axis.—Put $a=0$ and $c=0$, then

$$n = b \sin \phi, \tau-m = b \sin \phi \tan \delta,$$

$$\Delta s = \frac{b^2 \tan \phi}{2} (1 + \sin^2 \phi) - \frac{b^2 \sin \phi}{\cos \phi} - \frac{\cot \delta}{2} b^2 \sin^2 \phi \tan^2 \delta$$

$$= -\frac{b^2 \sin \phi}{2 \cos \phi} (1 - \sin^2 \phi) - \frac{b^2 \sin^2 \phi \tan \delta}{2}$$

$$= -\frac{b^2 \sin \phi}{2 \cos \delta} (\cos \phi \cos \delta + \sin \phi \sin \delta)$$

$$= -\frac{b^2 \sin \phi \cos (\phi - \delta)}{2 \cos \delta}$$

$$= -\frac{b^2 \sin \phi \cos z}{2 \cos \delta} \text{ for north stars}$$

$$= +\frac{b^2 \sin \phi \cos z}{2 \cos \delta} \text{ for south stars.}$$

The above formulæ agree with those of the "Survey of India Handbook." They can also be deduced from Mayer's formula for the correction to an observed transit by substituting the

value of τ corresponding to a , b , and c in the formula for circum-meridian altitudes—viz. $\frac{\tau^2}{2} \frac{\cos \phi \cos \delta}{\sin z}$, which is always subtractive from the observed zenith distance, and then correcting the result in the case of b and c by the corrections* to an observed zenith distance for an instrument out of level and collimation, viz.

$$\frac{b^2 \cot z}{2} \text{ and } \frac{c^2 \cot z}{2},$$

which are always additive to the observed zenith distance. For instance,

Collimation Error.— $\tau = c \sec \delta$.

Correction

$$\begin{aligned} &= \frac{c^2}{2} \cot z - \frac{c^2 \sec^2 \delta \cos \phi \cos \delta}{2 \sin z} \\ \Delta s &= \frac{c^2}{2 \sin z} \left(\cos z - \frac{\cos \phi}{\cos \delta} \right) = \frac{c^2}{2 \sin z \cos \delta} (\cos z \cos \delta - \cos \phi). \end{aligned}$$

If the star is N., $\phi = z - \delta$,

$$\begin{aligned} \Delta s &= \frac{c^2}{2 \sin z \cos \delta} (\cos z \cos \delta - \cos z \cos \delta - \sin z \sin \delta) \\ &= -\frac{c^2 \tan \delta}{2} \end{aligned}$$

as before.

Dislevelment Error.— $\tau = b \frac{\cos z}{\cos \delta}$,

$$\begin{aligned} \Delta s &= \frac{b^2 \cot z}{2} - \frac{b^2 \cos^2 z}{2 \cos^2 \delta} \cdot \frac{\cos \phi \cos \delta}{\sin z} \\ &= \frac{b^2 \cos z}{2 \sin z \cos \delta} (\cos \delta - \cos z \cos \phi). \end{aligned}$$

If the star be N., $z = \delta - \phi$ or $\delta = z + \phi$,

$$\begin{aligned} \Delta s &= \frac{b^2 \cos z}{2 \sin z \cos \delta} (\cos z \cos \phi - \sin z \sin \phi - \cos z \cos \phi) \\ &= -\frac{b^2 \sin \phi \cos z}{2 \cos \delta} \end{aligned}$$

as before.

The correction for azimuth deviation follows at once by substituting

$$\tau = \frac{a \sin (\phi - \delta)}{\cos \delta}.$$

When the three causes of error, a , b , and c , occur together the complete formula (C) should be used. Very erroneous results

* See Chauvenet, vol. ii. p. 327.

may be obtained by combining the formulæ for a , b , and c separately, as the complete expression contains the products of a , b , and c as well as their squares. The following example shows this (it must be remembered that the above expressions are to be multiplied by $\sin 1''$ if a , b , and c are given in seconds of arc):

$$a = +112'', \quad b = +25'', \quad c = +30''$$

$$\phi = +25^\circ, \quad \delta = +35^\circ, \quad z = 10^\circ.$$

$$\text{Correction for } c \text{ alone} = -0''00153$$

$$,, \quad ,, \quad a \quad ,, = -0''00584$$

$$,, \quad ,, \quad b \quad ,, = -0''00077$$

whereas correction for a , b , and c all occurring together $= +0''0228$, which is three times as great and of opposite sign to the sum of the three corrections taken separately. It must also be remembered that a , b , and c are considered in this formula as being positive when they all tend to make the transit of a south star occur too early.

Taiping, Perak: April 1899.

Small Nebulæ discovered with the Crossley Reflector of the Lick Observatory. By James E. Keeler, D.Sc., Director.

The following small nebulæ were found on two plates exposed with the Crossley reflector, for three and four hours respectively, for the purpose of photographing the spiral nebulæ $M\ 51$ in *Canes Venatici*. Assuming the position of the nucleus of the great spiral to be R.A. $= 13^h\ 25^m\ 39^s$, Decl. $= +47^\circ\ 42'6''$, as given by Roberts, the positions of the small nebulæ for 1900 are as below:

No.	R.A.			Decl.	Description.
	^h	^m	^s	^o	
1	13	23	02	+47 23'3	Round; diam. = 0'2.
2		24	17	26'5	Spindle-shaped; length = 1'9.
3		26	05	49'7	Very narrow; length = 0'6.
4		26	14	45'5	Round; diam. = 0'2; central condensation.
5		27	07	41'6	Round, diffuse; diam. = 0'3.
6		27	19	18'3	Round; diam. = 0'15.
7		27	33	19'8	Slightly elongated; major axis = 0'2.

No. 2 is long and narrow, with a bright, somewhat irregular axis. No. 3 and No. 4 are close to the great spiral, but apparently not connected with it. The former is recognisable on

the plate in Roberts's collection of photographs, though it is confused with the strongly granular background.

Although these nebulae are quite conspicuous on the photographs, I found, on examining them with the 36-inch refractor, that all but the brightest are nearly at the limit of visibility with that instrument. Several other faint nebulae, the positions of which were not noted, were observed during the search. In fact, this region seems to be filled with small, apparently unconnected nebulae, large numbers of which would doubtless be revealed by long-exposure photographs.

The plates used with the Crossley reflector measure $3\frac{1}{4} \times 4\frac{1}{4}$ inches, giving a field of only about one degree.

Note on the Nebula N.G.C. 6535 (R.A. $17^h 59^m$. N.P.D. $90^\circ 18'$).
By W. H. Robinson.

(Communicated by the Radcliffe Observer.)

This object was picked up with the Barclay Equatorial on May 3, 14^h , when it was fairly conspicuous and about $2'$ in diameter. It was also carefully observed with powers 45, 100, and 180 on May 5, 13^h , when "the nebula was rather bright near its centre, with several small stars on the preceding side. The diameter of the nebula was $90''$ approximately."

Immediately after my first observation, I identified it in Dr. Dreyer's most useful work, "New General Catalogue of Nebulae, &c.," and was surprised to find the following description in the column "Summary Description"—viz., "pF, vS," &c., or *pretty faint and very small*, &c.

The introduction of the above catalogue contains, p. 12, a progressive scale adopted in Dreyer's work, where *very small* corresponds to $10''$ to $12''$ diameter, and *pretty large* or *considerably large* would correspond with my estimations.

The nebula was discovered by Hind in 1852, who remarked that it was "*a nebulous object which does not occur in any of the Catalogues of Nebulae hitherto consulted. . . . It is very small and rather faint, perhaps $1'$ in diameter . . .*" (*Monthly Notices*, xii. 208).

Although Hind described the nebula as "*very small*," his qualifying note, "*perhaps $1'$ in diameter*," would place the object with *pretty large* nebulae on Dreyer's scale.

On looking up the other reference given by Dreyer—viz. Auwers 38—I found, *Königsberger Beob.* vol. xxxiv. p. 227, Auwers's heliometer observation gave $2'$ as the diameter of this nebula. This agrees very closely with the Barclay equatorial observation on 1899 May 3.

I would suggest that the nebula be described as pL instead of vS.

Radcliffe Observatory, Oxford:
1899 June 6.

Ephemerides of Two Situations in the Leonid Stream. By
G. Johnstone Stoney, M.A., D.Sc., F.R.S., and A. M. W.
Downing, M.A., D.Sc., F.R.S.

The *ortho-Leonids*, the dense part of the great procession, will probably be streaming across the Earth's orbit next November. The Earth will reach the node probably not far from the epoch 1899 November 15^d 18^h (see *Proceedings of the Royal Society*, vol. 64, p. 409). At that time, were it not for moonlight, an endlong photograph of the part of the stream which is near the Earth but outside the atmosphere might perhaps be secured by pointing the telescope along the tangent of the meteoric orbit, which would require it to be pointed towards a situation in the heavens some degrees distant from the radiant point. But as the moon will be nearly full, it seems hopeless to obtain this photograph.

Under these circumstances, and as Dr. Isaac Roberts expressed his willingness to make another attempt to photograph the *Leonids* while outside the Earth's atmosphere, the best course appeared to be to provide an ephemeris which will enable observations to be made on groups of nights upon which the Moon will not interfere, and which come near the date on which the Earth reaches the node. This is done in the subjoined ephemerides. The Earth is so situated on those dates that an actually tangential view of the stream cannot be obtained, and accordingly we had to be content with computing the ephemeris for situations in the stream where it makes a small angle with the line of sight. Two such situations were selected, one to be observed in the group of nights free from moonlight which come next before November 15, and the other to be observed in the group of dark nights following that date. The first of the selected stations is the perihelion of the osculating ellipse of the part of the stream which the Earth encountered in 1866, and the other is the point along the same ellipse of which the mean anomaly is 30°. The osculating ellipse was obtained by allowing for the perturbations since 1866, as calculated in a paper on the perturbations of the *Leonids* read before the Royal Society last March, and published in the *R. S. Proceedings*, vol. 64, p. 403.

The ephemerides have been computed both for the above mentioned points and for points along the ellipse close to them, in order that it may be possible for the observer to foresee the position in his field of view of the tangent to the meteoric orbit. It may be expected that the meteors, if they can be photographed at all, will present themselves as a dim streak,

like the faint part of a comet's tail, crossing the photographic plate in the direction so determined.

An inspection of the ephemerides shows that the direction in which the stream will cross the field of view in the observation to be made on the earlier group of nights is from the *nf* quadrant towards the *sp* quadrant, the position angle being about 50° on October 31, 40° on November 6, and 6° on November 12. In the observations to be made at the end of November and beginning of December, the apparent direction of the stream in the field of view will again be from the *nf* quadrant towards the *sp* quadrant, but the position angle will change but little during this fortnight. It will be between 53° and 55° .

Ephemeris I. records the apparent positions of the perihelion of the above mentioned osculating ellipse from midnight on 1899 October 31 till midnight on November 12.

Ephemeris II. records the apparent positions on the same dates of a point on the ellipse of which the mean anomaly is $0^\circ 1'$.

Ephemeris III. records the apparent positions as seen from the Earth at midnight from November 29 till December 11 of that point of the ellipse of which the mean anomaly is 30° .

Ephemeris IV. records the apparent positions on the same dates of a point on the ellipse of which the mean anomaly is 31° .

The computations have been made by Mr. Thomas Wright, of the staff of the *Nautical Almanac* Office, and the expense of the computation has been defrayed out of the Donation Fund of the Royal Society.

Greenwich, Midnight.		Right Ascension.						Declination.			
		I.			II.			I.		II.	
1899.		h	m	s	h	m	s	N	18°	$5'$	N $18^\circ 26'$
October	31	9	41	23	9	43	7				
November	1	9	44	10	9	45	54	18	4		18 27
	2	9	47	2	9	48	45	18	5		18 28
	3	9	50	0	9	51	41	18	6		18 30
	4	9	53	5	9	54	43	18	9		18 34
	5	9	56	20	9	57	55	18	13		18 39
	6	9	59	45	10	1	17	18	19		18 46
	7	10	3	23	10	4	51	18	27		18 56
	8	10	7	18	10	8	40	18	38		19 9
	9	10	11	36	10	12	49	18	52		19 25
	10	10	16	23	10	17	23	19	12		19 46
	11	10	21	47	10	22	29	19	37		20 12
	12	10	27	56	10	28	13	N 20	7		N 20 45

June 1899.

of the Leonid Stream.

541

Greenwich, Midnight, 1899.		Right Ascension.						Declination.					
		III.			IV.			III.			IV.		
		h	m	s	h	m	s	°	'	°	'	°	'
November	29	14	15	48	14	17	15	S 7	12	S 7	27		
	30	14	16	8	14	17	35	7	13	7	29		
December	1	14	16	28	14	17	54	7	14	7	30		
	2	14	16	48	14	18	13	7	16	7	31		
	3	14	17	7	14	18	32	7	17	7	32		
	4	14	17	26	14	18	51	7	18	7	34		
	5	14	17	44	14	19	10	7	19	7	35		
	6	14	18	3	14	19	28	7	21	7	36		
	7	14	18	21	14	19	46	7	22	7	37		
	8	14	18	39	14	20	4	7	23	7	38		
	9	14	18	57	14	20	22	7	24	7	39		
	10	14	19	15	14	20	40	7	25	7	40		
	11	14	19	33	14	20	58	S 7	25	S 7	41		

Observations of Comet a 1899 (Swift) made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The observations were made with the Sheepshanks Equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power, 55·

Greenwich Mean Solar Time.	Observer.	♂—★ R.A. h m s	Corr. for Refraction. s	Log. Factor of Parallax.	♂—★ N.P.D. ° ' "	Corr. for Refraction. "	Log. Factor of Parallax.	No. of Comps.	Apparent R.A. of Comet. h m s	Apparent N.P.D. of Comet. ° ' "	Comp Star.
1899. May 6 15 16 25	W.	—0 5·03	—0·02	9·6152	—9 29·7	—0·1	0·7653	6	23 49 21·69	62 32 12·5	a
7 14 47 12	"	+0 40·42	—0·04	9·6220	—14 29·1	—0·4	0·7781	6	23 45 14·09	61 28 41·0	b

Notes.

These observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

May 6.—Comet large and very bright, visible in twilight. Circular, about 5' in diameter, with a central condensation.

May 7.—There was a well-defined nucleus.

The initial W. is that of Mr. Witchell.

<i>Comparison Stars.</i>			<i>Authority.</i>	
Star's Name.	Assumed R.A. 1899°. h m s	Assumed N.P.D. 1899°. ° ' "		
a B.D. +27° No. 4640	23 49 25·65	62 41 43·6	Cambridge Astr. Gesell. Catalogue, 14341.	
b 79 Pegasi	23 44 32·59	61 43 11·5	Greenwich Ten-Year Catalogue, 1890 (MSS.).	

Royal Observatory, Greenwich:
1899 June 9.

Equatorial Comparisons of Jupiter, Uranus and Neptune with certain Stars in Newcomb's Standard Catalogue. By John Tebbutt.

The accompanying observations have been made with the 8-inch equatorial refractor and filar-micrometer, and under favourable conditions. In the comparisons of *Jupiter* the first and second limbs were both observed at each transit, and the north and south limbs alternately; in those of *Uranus* the planet's centre was observed on April 18 and May 16, and on each intermediate date the first and north and the second and south limbs alternately; the centre of *Neptune* was observed throughout. In the reduction to the centres the data of the *Nautical Almanac* were employed. The differential co-ordinates have been corrected for refraction and a small error in the perpendicularity of the micrometer threads. The adopted mean places of the comparison stars are the results of an elaborate investigation by Mr. C. J. Merfield, F.R.A.S., from all available catalogues, and are as follows:—

Star.	Epoch.	Mean R.A.			No. of Cata- logue.	No. of Obs.	Mean N.P.D.			No. of Cata- logue.	No. of Obs.
		h	m	s							
η Virginis	1898.0	12	14	41.20	44	1161	90	6	0.0	41	731
ω^1 Scorpii	1898.0	16	0	50.39	18	80	110	23	35.5	18	76
ω^2 Scorpii	1898.0	16	1	25.35	22	118	110	35	36.1	21	108
114 (o) Tauri	1899.0	5	21	34.10	25	99	68	8	58.2	23	1

The planet observations are compared respectively with the mean noon ephemeris of *Jupiter* and with the transit ephemerides of *Uranus* and *Neptune* of the *Nautical Almanac*. Weighting the results according to the number of comparisons in each we have the following for the mean corrections to the *Nautical Almanac*:—

From Jupiter and η Virginis	Δ R.A. = +0.09	Δ N.P.D. = -0.5
„ Uranus and ω^1 Scorpii	„ -0.20	„ +0.8
„ Uranus and ω^2 Scorpii	„ -0.20	„ +0.3
„ Neptune and 114 (o) Tauri	„ -0.32	„ +2.6

Date.	Windsor Mean Time.	Comps.	Planet's Centre		Star Reductions. R.A. N.P.D.	Parallax Corrections. R.A. N.P.D.	Geocentric Apparent Place of Planet's Centre. R.A. N.P.D.		Corrections to <i>Nautical Almanac.</i> R.A. N.P.D.			
			R.A.	-Star. N.P.D.			R.A.	N.P.D.		R.A.	N.P.D.	
<i>Jupiter and η Virginis.</i>												
1808. April 2	h m s 9 58 27	10	m s + 4 3'42	' '' + 11 20'8	s + 2'94	' '' + 19'4	s - 0'05	' '' + 1'1	h m s 12 18 47'51	' '' 90 17 41'3	s + 0'02	' '' + 0'4
" 3	10 21 42	10	+ 3 35'13	+ 8 19'4	+ 2'94	+ 19'4	- 0'03	+ 1'1	12 18 19'24	90 14 39'9	+ 0'08	+ 0'1
" 4	8 53 53	14	+ 3 9'06	+ 5 33'2	+ 2'95	+ 19'4	- 0'07	+ 1'1	12 17 53'14	90 11 53'7	+ 0'02	- 0'1
" 6	9 37 40	20	+ 2 13'37	- 0 21'6	+ 2'95	+ 19'4	- 0'05	+ 1'1	12 16 57'47	90 5 58'9	+ 0'08	- 0'6
" 7	9 13 8	20	+ 1 46'77	- 3 10'5	+ 2'95	+ 19'4	- 0'06	+ 1'1	12 16 30'86	90 3 10'0	+ 0'14	- 0'6
" 8	8 44 32	8	+ 1 20'39	- 5 57'7	+ 2'95	+ 19'4	- 0'07	+ 1'1	12 16 4'47	90 0 22'8	+ 0'13	- 1'2
" 9	8 11 40	9	+ 0 54'33	- 8 42'4	+ 2'96	+ 19'4	- 0'08	+ 1'1	12 15 38'41	89 57 38'1	+ 0'14	- 1'5
<i>Uranus and ω¹ Scorpii.</i>												
1808. April 18	h m s 11 31 20	15	m s + 2 26'60	' '' ...	s + 3'21	' '' ...	s - 0'02	' '' ...	h m s 16 3 20'18	' '' ...	s - 0'21	' '' ...
" 19	11 13 43	14	+ 2 18'63	...	+ 3'23	...	- 0'02	...	16 3 12'23	...	- 0'22	...
" 21	11 27 12	10	+ 2 2'10	...	+ 3'28	...	- 0'02	...	16 2 55'75	...	- 0'16	...
" 27	11 27 10	12	+ 1 9'55	...	+ 3'40	...	- 0'02	...	16 2 3'32	...	- 0'19	...
" 28	10 15 10	14	+ 1 0'82	...	+ 3'42	...	- 0'02	...	16 1 54'61	...	- 0'23	...
" 29	10 45 2	14	+ 0 51'49	...	+ 3'44	...	- 0'02	...	16 1 45'30	...	- 0'12	...
May 7	9 36 16	9	- 0 25'30	+ 2 33'7	+ 3'58	+ 13'2	- 0'02	+ 0'2	16 0 28'65	110 26 22'6	- 0'23	+ 1'1
" 8	9 42 37	20	- 0 35'35	+ 2 5'4	+ 3'60	+ 13'3	- 0'02	+ 0'2	16 0 18'62	110 25 54'4	- 0'25	+ 1'0
" 13	10 1 44	14	- 1 26'13	- 0 17'4	+ 3'67	+ 13'3	- 0'02	+ 0'1	15 59 27'91	110 23 31'5	- 0'16	+ 0'8
" 16	10 4 54	10	- 1 57'15	- 1 45'4	+ 3'72	+ 13'4	- 0'02	+ 0'1	15 58 56'94	110 22 3'6	- 0'20	+ 0'2

Date.	Windsor Mean Time.		Comps.		Planet's Centre —Star.		Star Reductions.		Parallax Corrections.		Geocentric Apparent Place of Planet's Centre.			Corrections to Nautical Almanac.	
	h	m	s		R.A.	N.P.D.	R.A.	N.P.D.	R.A.	N.P.D.	h	m	s	R.A.	N.P.D.
1898.															
April 18	11	31	20	15	+1 51'69	— 1 31'4	+3'22	+12'6	—0'02	+0'1	16	3	20'24	—0'15	+0'2
" 19	11	13	43	14	+1 43'71	— 1 53'4	+3'24	+12'6	—0'02	+0'2	16	3	12'28	—0'17	+0'1
" 21	11	27	12	10	+1 27'19	— 2 38'4	+3'28	+12'7	—0'02	+0'1	16	2	55'80	—0'11	+0'6
" 27	11	27	10	12	+0 34'51	— 5 3'9	+3'40	+12'9	—0'02	+0'1	16	2	3'24	—0'27	+0'1
" 28	10	15	10	14	+0 25'87	— 5 28'1	+3'43	+12'9	—0'02	+0'2	16	1	54'63	—0'21	+0'1
" 29	10	45	2	14	+0 16'43	— 5 53'7	+3'44	+13'0	—0'02	+0'1	16	1	45'20	—0'22	+0'6
May 7	9	36	16	9	—1 0'23	...	+3'59	...	—0'02	...	16	0	28'69	—0'19	...
" 8	9	42	37	20	—1 10'30	...	+3'60	...	—0'02	...	16	0	18'63	—0'24	...
" 13	10	1	44	14	—2 1'20	...	+3'68	...	—0'02	...	15	59	27'81	—0'26	...
" 16	10	4	54	10	—2 32'07	...	+3'73	...	—0'02	...	15	58	56'99	—0'15	...
<i>Neptune and 114 (o) Tauri.</i>															
1899															
Feb. 22	9	53	9	10	+3 52'90	— 2 53'8	+2'26	— 3'0	+0'01	+0'2	5	25	29'27	—0'34	+3'1
" 23	8	50	0	10	+3 51'68	— 2 55'5	+2'24	— 3'0	+0'01	+0'2	5	25	28'03	—0'41	+3'4
" 24	8	31	55	16	+3 50'69	— 2 58'9	+2'23	— 3'0	+0'01	+0'2	5	25	27'03	—0'35	+2'2
" 25	8	29	43	15	+3 49'85	— 3 0'9	+2'21	— 3'0	+0'01	+0'2	5	25	26'17	—0'28	+2'5
" 27	8	39	52	15	+3 48'39	— 3 6'2	+2'18	— 2'9	+0'01	+0'2	5	25	24'68	—0'32	+2'3
" 28	8	23	50	14	+3 47'97	— 3 8'5	+2'16	— 2'9	+0'01	+0'2	5	25	24'24	—0'27	+2'7

Peninsula Observatory, Windsor, N.S. Wales;
1899 May 1.

Ephemeris for Physical Observations of the Moon for the Second Half of 1899. By A. C. D. Crommelin.

Greenwich Midnight.	Selenographical		Geocentric Libration		Combined Amount.	Direc- tion.
	Colong. of the Sun.	Lat. of the Sun.	Sel. Long. of the Earth.	Lat. of the Earth.		
1899. July 1	195°76	-0°30	+0°74	-5°71	8°83	229°7
2	208°00	0°33	+6°59	-4°72	8°11	234°4
3	220°24	0°35	+6°15	-3°52	7°07	240°2
4	232°49	0°37	+5°47	-2°17	5°91	248°4
5	244°73	0°40	+4°58	-0°75	4°63	260°7
6	256°98	0°42	+3°52	+0°70	3°59	281°2
7	269°24	-0°44	+2°33	+2°09	3°12	311°9
8	281°49	0°47	+1°05	+3°38	3°55	342°7
9	293°74	0°49	-0°28	+4°52	4°54	3°5
10	305°98	0°51	-1°63	+5°46	5°68	16°6
11	318°22	0°53	-2°95	+6°16	6°84	25°6
12	330°47	0°56	-4°19	+6°61	7°80	32°4
13	342°70	-0°58	-5°31	+6°77	8°60	38°1
14	354°93	0°61	-6°24	+6°63	9°08	43°3
15	7°16	0°63	-6°93	+6°17	9°29	48°3
16	19°38	0°66	-7°30	+5°41	9°05	53°5
17	31°59	0°68	-7°31	+4°33	8°48	59°4
18	43°79	0°71	-6°90	+2°99	7°52	66°6
19	55°99	-0°74	-6°06	+1°42	6°24	76°8
20	68°19	0°76	-4°79	-0°28	4°80	93°3
21	80°37	0°79	-3°15	-2°00	3°72	122°4
22	92°56	0°82	-1°25	-3°61	3°82	160°9
23	104°74	0°85	+0°79	-4°98	5°03	189°0
24	116°93	0°87	+2°78	-5°98	6°58	204°9
25	129°12	-0°89	+4°57	-6°57	8°01	214°8
26	141°32	0°92	+6°03	-6°71	8°99	221°9
27	153°53	0°94	+7°05	-6°44	9°52	227°6
28	165°74	0°96	+7°62	-5°80	9°60	232°7
29	177°96	0°98	+7°74	-4°86	9°13	237°9
30	190°18	0°99	+7°46	-3°69	8°36	243°7
31	202°41	-1°01	+6°84	-2°38	7°25	250°8
Aug. 1	214°65	1°03	+5°94	-0°98	6°00	260°6
2	226°89	-1°04	+4°85	+0°43	4°87	275°1

Greenwich Midnight.	Selenographical Colong. of the Sun.	Lat. of the Sun.	Geocentric Libration Sel. Long. Lat. of the Earth.	Combined Amount.	Direct- tion.
1899.					
Aug. 3	239°13	-1°06	+3°62 +1°81	4°05	296°6
4	251°38	1°08	+2°31 +3°08	3°85	323°1
5	263°62	1°09	+0°96 +4°25	4°38	347°3
6	275°87	-1°11	-0°38 +5°21	5°23	4°2
7	288°11	1°12	-1°70 +5°95	6°19	16°0
8	300°35	1°14	-2°96 +6°43	7°07	24°7
9	312°59	1°16	-4°13 +6°63	7°82	31°9
10	324°83	1°17	-5°19 +6°54	8°37	38°4
11	337°06	1°19	-6°09 +6°15	8°67	44°7
12	349°29	-1°21	-6°78 +5°47	8°68	51°1
13	1°51	1°23	-7°23 +4°50	8°53	58°1
14	13°72	1°25	-7°35 +3°28	8°01	66°0
15	25°93	1°26	-7°09 +1°84	7°30	75°5
16	38°13	1°28	-6°41 +0°25	6°42	87°8
17	50°32	1°30	-5°28 -1°41	5°49	105°0
18	62°50	-1°32	-3°74 -3°01	4°79	128°8
19	74°69	1°33	-1°85 -4°44	4°80	157°4
20	86°87	1°35	+0°25 -5°57	5°58	182°6
21	99°14	1°36	+2°38 -6°30	6°74	200°7
22	111°22	1°38	+4°36 -6°58	7°90	213°5
23	123°40	1°39	+5°99 -6°42	8°80	223°0
24	135°59	-1°40	+7°18 -5°85	9°26	230°8
25	147°78	1°41	+7°87 -4°95	9°29	237°8
26	159°98	1°42	+8°04 -3°81	8°92	244°6
27	172°19	1°43	+7°76 -2°51	8°15	252°1
28	184°40	1°43	+7°08 -1°12	7°15	261°0
29	196°62	-1°44	+6°11 +0°29	6°12	272°7
30	208°84	1°44	+4°93 +1°66	5°23	288°6
31	221°07	1°45	+3°62 +2°94	4°67	309°1
Sept. 1	233°29	1°45	+2°26 +4°08	4°65	331°0
2	245°52	-1°46	+0°90 +5°05	5°14	349°9
3	257°76	-1°47	-0°41 +5°80	5°82	4°0
4	269°99	1°47	-1°65 +6°29	6°48	14°7
5	282°23	1°48	-2°79 +6°52	7°11	23°2
6	294°46	1°48	-3°82 +6°45	7°55	30°6
7	306°69	1°49	-4°73 +6°09	7°74	37°8
8	318°92	1°49	-5°50 +5°43	7°70	45°4
9	331°14	-1°50	-6°10 +4°51	7°56	53°6

Greenwich Midnight.	Selenographical Colong. Lat. of the Sun.	Geocentric Libration Sel. Long. Lat. of the Earth.	Combined Amount.	Direc- tion.		
1899. Sept. 10	343°36	-1°51	-6°49	+3°34	7°27	62°8
11	355°57	1°51	-6°63	+1°98	6°90	73°4
12	7°77	1°52	-6°47	+0°47	6°48	85°8
13	19°97	1°52	-5°94	-1°10	6°06	100°5
14	32°16	1°53	-5°03	-2°65	5°68	117°8
15	44°34	-1°53	-3°73	-4°07	5°53	137°5
16	56°51	1°53	-2°08	-5°24	5°66	158°3
17	68°68	1°54	-0°19	-6°07	6°08	178°2
18	80°84	1°54	+1°80	-6°49	6°75	195°5
19	93°01	1°53	+3°71	-6°45	7°42	209°9
20	105°17	1°53	+5°34	-5°98	8°01	221°8
21	117°34	-1°53	+6°56	-5°13	8°33	232°0
22	129°51	1°52	+7°31	-4°01	8°33	241°3
23	141°69	1°52	+7°55	-2°69	8°00	250°4
24	153°87	1°51	+7°33	-1°27	7°40	260°2
25	166°06	1°51	+6°69	+0°17	6°69	271°5
26	178°25	1°50	+5°74	+1°56	5°97	285°2
27	190°45	-1°49	+4°53	+2°86	5°35	302°2
28	202°65	1°48	+3°26	+4°02	5°19	321°0
29	214°86	1°48	+1°91	+5°00	5°35	339°1
30	227°07	1°47	+0°58	+5°76	5°81	354°2
Oct. 1	239°29	1°46	-0°68	+6°28	6°34	6°2
2	251°50	1°45	-1°80	+6°52	6°78	15°4
3	263°72	-1°45	-2°79	+6°47	7°06	23°3
4	275°94	1°44	-3°63	+6°13	7°11	30°6
5	288°16	1°43	-4°30	+5°48	6°96	38°1
6	300°38	1°42	-4°82	+4°56	6°65	46°6
7	312°59	1°42	-5°17	+3°39	6°20	56°7
8	324°80	1°41	-5°36	+2°03	5°74	69°3
9	337°01	-1°40	-5°35	+0°54	5°39	84°2
10	349°20	1°39	-5°11	-1°01	5°21	101°2
11	1°39	1°39	-4°61	-2°53	5°26	118°8
12	13°58	1°38	-3°84	-3°93	5°50	135°7
13	25°75	1°37	-2°77	-5°12	5°85	151°6
14	37°92	1°36	-1°44	-6°00	6°18	166°5
15	50°08	-1°35	+0°08	-6°50	6°50	180°7
16	62°24	1°33	+1°69	-6°57	6°77	194°4
17	74°39	-1°31	+3°24	-6°21	7°02	207°6

Greenwich Midnight.	Selenographical Colong. of the Sun.	Lat.	Geocentric Libration Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.
1899. Oct. 18	86° 54	-1° 30	+4° 59	-5° 45	7° 14	220° 1
19	98° 69	1° 28	+5° 65	-4° 37	7° 06	232° 3
20	110° 84	1° 26	+6° 29	-3° 05	6° 98	244° 1
21	122° 99	-1° 24	+6° 51	-1° 59	6° 71	256° 3
22	135° 15	1° 22	+6° 31	-0° 10	6° 31	279° 1
23	147° 31	1° 20	+5° 72	+1° 36	5° 89	283° 4
24	159° 48	1° 18	+4° 82	+2° 73	5° 54	299° 5
25	171° 66	1° 16	+3° 70	+3° 94	5° 40	316° 8
26	183° 84	1° 14	+2° 44	+4° 97	5° 52	333° 9
27	196° 02	-1° 12	+1° 12	+5° 77	5° 89	349° 0
28	208° 21	1° 10	-0° 17	+6° 33	6° 33	1° 5
29	220° 40	1° 08	-1° 36	+6° 62	6° 75	11° 6
30	232° 60	1° 06	-2° 41	+6° 62	7° 02	20° 0
31	244° 80	1° 04	-3° 27	+6° 32	7° 11	27° 4
Nov. 1	257° 00	1° 03	-3° 91	+5° 71	6° 91	34° 4
2	269° 20	-1° 01	-4° 33	+4° 80	6° 48	42° 1
3	281° 41	0° 99	-4° 53	+3° 64	5° 80	51° 2
4	293° 61	0° 97	-4° 54	+2° 26	5° 08	63° 5
5	305° 81	-0° 95	-4° 35	+0° 73	4° 39	80° 5
6	318° 01	-0° 94	-3° 99	-0° 86	4° 07	102° 2
7	330° 20	0° 92	-3° 46	-2° 43	4° 22	125° 1
8	342° 39	0° 90	-2° 77	-3° 87	4° 76	144° 4
9	354° 57	0° 88	-1° 93	-5° 09	5° 45	159° 2
10	6° 74	0° 86	-0° 95	-6° 01	6° 09	171° 0
11	18° 91	0° 83	+0° 14	-6° 57	6° 57	181° 2
12	31° 06	-0° 81	+1° 29	-6° 73	6° 86	190° 8
13	43° 21	0° 78	+2° 43	-6° 47	6° 92	200° 6
14	55° 35	0° 75	+3° 49	-5° 91	6° 85	210° 6
15	67° 49	0° 73	+4° 38	-4° 81	6° 49	222° 3
16	79° 63	0° 70	+5° 03	-3° 54	6° 14	234° 9
17	91° 77	0° 67	+5° 38	-2° 09	5° 76	248° 8
18	103° 90	-0° 64	+5° 41	-0° 56	5° 44	264° 1
19	116° 04	0° 61	+5° 11	+0° 96	5° 21	280° 6
20	128° 18	0° 59	+4° 49	+2° 41	5° 07	298° 2
21	140° 33	0° 56	+3° 61	+3° 71	5° 16	315° 8
22	152° 48	0° 53	+2° 53	+4° 82	5° 45	332° 3
23	164° 64	0° 50	+1° 31	+5° 70	5° 87	347° 1
24	176° 80	-0° 47	+0° 02	+6° 34	6° 34	359° 8

Greenwich Midnight.	Selenographical		Geocentric Libration		Combined Amount.	Direc- tion.
	Colong. of the Sun.	Lat.	Sel. Long. of the Earth.	Lat.		
1899. Nov. 25	188° 97	- 0° 44	- 1° 26	+ 6° 70	6° 83	10° 7
26	201° 14	0° 41	- 2° 43	+ 6° 78	7° 19	19° 7
27	213° 31	0° 39	- 3° 45	+ 6° 56	7° 41	27° 7
28	225° 49	0° 36	- 4° 26	+ 6° 03	7° 36	35° 2
29	237° 68	0° 34	- 4° 81	+ 5° 20	7° 07	42° 7
30	249° 87	- 0° 31	- 5° 05	+ 4° 16	6° 56	50° 5
Dec. 1	262° 06	0° 29	- 5° 00	+ 2° 74	5° 70	61° 3
2	274° 26	0° 26	- 4° 65	+ 1° 20	4° 79	75° 5
3	286° 45	0° 24	- 4° 03	- 0° 44	4° 06	96° 2
4	298° 64	0° 22	- 3° 20	- 2° 08	3° 81	123° 0
5	310° 84	0° 19	- 2° 20	- 3° 61	4° 22	148° 6
6	323° 02	- 0° 17	- 1° 09	- 4° 92	5° 02	167° 5
7	335° 20	0° 14	+ 0° 05	- 5° 94	5° 94	180° 5
8	347° 37	0° 11	+ 1° 18	- 6° 58	6° 71	190° 2
9	359° 54	0° 08	+ 2° 24	- 6° 81	7° 15	198° 2
10	11° 69	0° 06	+ 3° 17	- 6° 63	7° 37	205° 6
11	23° 84	- 0° 03	+ 3° 95	- 6° 06	7° 21	213° 1
12	35° 98	0° 00	+ 4° 55	- 5° 15	6° 90	221° 5
13	48° 12	+ 0° 04	+ 4° 94	- 3° 96	6° 32	231° 3
14	60° 25	0° 07	+ 5° 11	- 2° 57	5° 72	243° 3
15	72° 38	0° 10	+ 5° 04	- 1° 07	5° 14	258° 0
16	84° 51	0° 13	+ 4° 74	+ 0° 47	4° 77	275° 7
17	96° 64	0° 16	+ 4° 21	+ 1° 95	4° 63	294° 9
18	108° 77	0° 20	+ 3° 47	+ 3° 32	4° 79	313° 7
19	120° 91	+ 0° 23	+ 2° 53	+ 4° 50	5° 18	330° 7
20	133° 04	0° 26	+ 1° 43	+ 5° 47	5° 63	345° 3
21	145° 18	0° 29	+ 0° 21	+ 6° 19	6° 19	358° 1
22	157° 33	0° 32	- 1° 06	+ 6° 63	6° 70	9° 1
23	169° 48	0° 35	- 2° 34	+ 6° 80	7° 21	19° 0
24	181° 63	0° 37	- 3° 55	+ 6° 67	7° 54	28° 0
25	193° 79	+ 0° 40	- 4° 62	+ 6° 25	7° 75	36° 5
26	205° 96	0° 42	- 5° 47	+ 5° 53	7° 80	44° 7
27	218° 13	0° 45	- 6° 05	+ 4° 54	7° 56	53° 1
28	230° 31	0° 47	- 6° 28	+ 3° 28	7° 10	62° 5
29	242° 49	0° 50	- 6° 13	+ 1° 82	6° 38	73° 5
30	254° 67	0° 52	- 5° 58	+ 0° 11	5° 58	88° 9
31	266° 87	0° 54	- 4° 64	- 1° 46	4° 87	107° 5
1900. Jan. 1	279° 06	+ 0° 57	- 3° 38	- 3° 07	4° 56	132° 2

This ephemeris has been constructed for Greenwich midnight instead of noon as heretofore. It is hoped that this change will render its use more convenient to observers in Europe.

The longitudes are reckoned in the plane of the Moon's equator, the axis of reference being the radius which passes through the mean centre of the visible disc. This axis therefore rotates with the Moon, and is not fixed in space.

The inclination of the Moon's equator to the ecliptic is taken as $1^{\circ}523$, the value used in the *Connaissance des Temps*, that given by the *Nautical Almanac* being $1^{\circ}536$.

The principal term of the physical libration in longitude has been applied as before, the expression for it being $-0^{\circ}037 \times \text{sine Sun's mean anomaly}$.

The colongitude of the Sun is 90° (or 450°) minus his selenographical longitude. It also is the selenographical longitude of the morning terminator reckoned eastward from the mean centre of the disc. Hence its value is approximately 270° , 0° , 90° , 180° at new Moon, first quarter, full Moon, last quarter respectively. The longitude of the evening terminator is of course 180° greater or less than that of the morning one.

When the geocentric libration in longitude is positive, the region brought into view is on the west limb; when negative, on the east.

When the geocentric libration in latitude is positive, the region brought into view is at the Moon's north pole; when negative, at the south.

The column "Combined Amount" gives the distance between the apparent and mean centres of the disc, and the column "Direction" gives the position angle of the apparent centre from the mean centre, or, which is the same thing, the position angle of the region which is most carried into view by libration. The angles are reckoned eastward from the northern extremity of the Moon's axis.

The terms "East" and "West" are used throughout with reference to our sky, and not as they would appear to an observer on the Moon.

Benvenue, 55 Ulundi Road, Elckheath, S.E. :
1899 June 10.

CONTENTS.

	PAGE
Fellow elected	523
Candidates proposed	<i>ib.</i>
Presents announced.	<i>ib.</i>
A. W. Roberts, A further investigation concerning the position error affecting eye-estimates of star magnitudes	524
A. R. Hinks, Note on the construction and use of Réseaux	530
A. E. Young, On the formulæ of reduction to the meridian of the observed zenith distances of stars	532
J. E. Keeler, Small Nebulæ discovered with the Crossley reflector of the Lick Observatory	537
W. H. Robinson, Note on the Nebula N.G.C. 6535	538
G. Johnstone Stoney and A. M. W. Downing, Ephemerides of two situa- tions in the <i>Leonid</i> stream	539
Royal Observatory, Greenwich, Observations of Comet <i>a</i> 1899 (Swift)	542
John Tebbutt, Equatorial comparisons of <i>Jupiter</i> , <i>Uranus</i> and <i>Neptune</i> with certain stars in Newcomb's Standard Catalogue	543
A. C. D. Crommelin, Ephemeris for physical observations of the Moon for the second half of 1899	546

